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## VELOCITY MICROHABITATS IN THE EDGES OF THE CHANNELIZED MISSOURI RIVER

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### ABSTRACT

Mean column velocity in the filling bank of the channelized Missouri River reached a maximum of 0.875 m/s. In these locations nose velocity was 30% less. Increased volume discharge did not result in increased velocity in the filling bank locations studied. Surface velocity did not exceed 0.5 m/s within the first 3 m from the cutting bank at two locations along the channelized Missouri River near Nebraska City and Tekamah, Nebraska. Within column velocity at the Nebraska City site was typically higher than velocity near the surface and nearer the bottom. However, at the Tekamah site surface velocity was frequently higher than either mid-column or near-bottom velocity. Velocity preferences for native Missouri River fish species were usually much higher than those observed within the filling bank locations and within a quite wide margin along the cutting bank.

† † †

Odum (1959) described the tendency for increased variety and density at community junctions as the *edge effect*. Hynes (1970) discussed the microhabitat zones along streams known as psammon (wet sands at the margins) and madicolous (the thin zone of water flowing over rock faces) which develop unique faunal assemblages. Moreover, the hyporheic zone (the loose interstitial space in the bottom sediments) provides a microhabitat of great importance in streams since many aquatic invertebrates live in this zone (Ward and Stanford, 1989). Water exchange between saturated sediments and open channels can significantly alter stream water chemistry, and the extent to which stream organic matter is stored in these sediments is a function of velocity (Findlay, 1995).

Edge is an especially important zone in large rivers today because so many large rivers have been channelized, thus eliminating historical channel mor-

phology. The old channel configuration had a diversity of habitats which included numerous sandbars and backwaters. Depth was important as cover and was associated with sandbar pools where velocity was low. Today the only area with appreciable overhead cover consists of a narrow strip along the channel margins (Stalnaker et al., 1989); main channels in the channelized reach lack sandbar pool habitat at normal navigation discharge.

The U.S. Army Corps of Engineers contracted with the U.S. Geological Survey in 1990 and 1991 to obtain cross-section depth and velocity profiles from the channelized Missouri River at selected locations throughout the entire reach from about the Little Sioux River confluence to the Mississippi River confluence. These data were obtained to provide insight on native fish habitat quality as it related to discharge and operation of the mainstem dams for the Review and Update of the Master Water Control Manual (Cieslik et al., 1993; Latka et al., 1993). These data typically explored the macro-environment with respect to velocity in the navigation channel, and only a small number of velocity readings were taken in near-shore microhabitats. For this reason a more detailed analysis of the depth and velocity relationship was necessary for the edge microhabitats of the channelized Missouri River since it is in these edges that most fish are located; in fact, few fish live in the thalweg.

The purpose of the research reported herein was to obtain velocity data from the substrate-water interfaces (nose velocity) of areas along both the filling and cutting banks of the channelized Missouri River on the Nebraska shore, and to compare nose velocity with mean column velocity or surface velocity.

## METHODS

The study was carried out in 1990–92. The first study in 1990 was an effort to establish techniques. Two wing dikes (i.e., dikes 745.3 and 745.05) were selected for study near Decatur, Nebraska. A steel cable tagline was stretched from the tip of the upstream dike to the tip of the downstream dike. A boat was attached to the tagline and depth and velocity were obtained at 28 intervals along this transect. Depth was measured with a telescoping fiberglass leveling rod. Velocity was obtained near the bottom and was termed nose velocity. A USGS Type AA current meter was attached to a 22.7-kg lead sounding weight that was lowered to the bottom. The meter was attached to the weight with a special framework that positioned it just in front of the sounding weight and in such a manner that when the weight was on the bottom the meter was suspended near the bed surface. This transect was studied once, on 22 May 1990.

A new study area was established in 1991 near Dakota City, Nebraska. A three-wing dike field was selected (i.e., wing dikes 799.5, 799.3, and 799.2). A tagline was stretched from the lowermost dike across the center dike and to the uppermost dike. This was done at two locations (i.e., one transect was nearer the proximal end of the dike and another transect was nearer the distal end of the dike). A boat was attached to the taglines and depth and velocity at more than 35 locations were obtained from the dike field in May, July, and September of 1991, in addition to triplicate orange-peel dredge samples in each cell to characterize sediment type, organic matter content, and macro-invertebrate community structure. This paper will describe the depth and velocity data. Depth and velocity were measured in the same manner that was developed in the pilot study in 1990.

In addition, artificial substrate samplers were placed on the center wing dike and recovered in May, July, and September. Depth and velocity were measured at the samplers on the upstream, downstream, proximal, and distal sections of the dike. Artificial substrate samplers were also placed on the cutting bank immediately across the channel and recovered in the same manner as the filling bank samplers; depth and velocity were obtained as the samplers were retrieved. This report will describe only the depth and velocity portion of this study.

Revetment velocity was investigated in greater detail in the final phase of this study during March of 1992. One study area was established on the exact transect location used by the USGS during Master Manual studies near Tekamah, Nebraska, at a site known as Deer Island (river mile marker 672.3), and a

second site was established near Nebraska City, Nebraska, at the same location used by the USGS (river mile marker 564.6).

The following procedure was developed to obtain precise velocities from revetment microhabitats. The bow of a long boat was firmly attached to the bankline and the stern was winched perpendicular to the bankline with a heavy cable and winch and secured in this position for the duration of the study. Two heavy pipes were fastened perpendicular to the boat and parallel to the bank, one at the bow and one at the stern. A bridge-board was attached to the pipes in a manner to be suspended over the river upstream from the boat and 1 m away from it. Paired nails had been previously driven at small increments along the bridge-board. Once the bridge-board was in place securely, the distance from the water's edge to each pair of nails was recorded. The cable for the current meter was subsequently suspended between paired nails and velocity was measured at the surface with the meter positioned 100 mm below the water surface. The meter was subsequently moved in stepwise fashion from the water edge toward the river channel, and as depth increased, velocity was measured at several locations within the column as well as at the surface. Depth was measured with a leveling rod. Placement of the current meter in relation to the sounding weight was different for this study in order to minimize damage to the current meter from the large rock revetment substrates. It was attached in a conventional manner using a standard 305 mm hanger bar and a smaller 13.6-kg lead sounding weight. In this manner, the meter was suspended between the lifting cable and the weight, approximately 305 mm from the bottom of the sounding weight.

## RESULTS

### Decatur study

A pilot study was conducted in 1990 at Decatur, Nebraska, to determine if a tagline would hold a boat in what was expected to be moderately high current speed near the distal end of a wing dike. Discharge on 22 May was 683 m<sup>3</sup>/s. Moreover, it was necessary to develop a method to measure velocity very near the water-substrate interface, and to select the appropriate benthic dredge for sampling the compacted sediments expected to occur there. Depth was effectively measured with a telescoping fiberglass leveling rod.

The current pattern which developed near wing dikes caused a scour hole to form both upstream and downstream from the dike. The downstream hole at the tip of the dike was shallower than the hole just upstream of the next dike downriver (Table 1). Depth in this dike field ranged from 1.19 to 4.85 m.

Table 1. Nose velocity on a transect from wing dike tip to wing dike tip (filling bank) near Decatur, Nebraska, at river mile marker 691.8 on the Missouri River on 22 May 1990 when the discharge was 682 m<sup>3</sup>/s.

Distance from the water edge of upstream dike to the downstream dike (m)	Depth (m)	Nose velocity (m/s)
6.10	2.83	0.401
12.19	1.55	0.533
18.29	1.19	0.430
24.38	1.19	0.283
30.48	2.44	0.162
36.58	3.26	0.268
42.67	3.60	0.407
48.77	3.35	0.500
54.86	2.96	0.582
60.96	2.38	0.664
67.06	2.16	0.546
73.15	2.01	0.680
79.25	1.92	0.619
85.34	2.01	0.533
91.44	1.98	0.512
97.54	2.16	0.512
103.63	2.01	0.582
109.73	2.07	0.607
115.82	2.13	0.546
121.92	2.62	0.249
128.02	2.56	0.475
134.11	2.62	0.515
140.21	3.11	0.344
146.30	2.96	0.607
152.40	3.44	0.457
158.50	4.85	0.326
164.59	3.47	0.847
170.69	0.0	0.0

Nose velocity ranged from 0.16 m/s to as high as 0.847 m/s (Table 1). The highest velocity occurred just upstream from the lowermost dike, where the river was directed out and around the tip. There was considerable variation, however, and the lowest velocity was found after the depth decreased on the leeward side of the upstream dike. The river was rising during 22 May and enough precipitation occurred that further investigation was terminated. Discharge was 1,048 m<sup>3</sup>/s by midnight on the 23rd.

#### Dakota City study

The information obtained during 1990 suggested that a more detailed investigation was possible. A study area near Dakota City, Nebraska, was selected for 1991 studies. The design included two transects across three wing dikes parallel to the flow in the

channel. One was near the proximal ends of the dikes and another transect was near the distal end (Fig. 1). This approach allowed measurement at a wider variety of depths. The tagline winch was chained to a piling in the most downstream dike and the cable was drawn by boat to the center dike, hand-pulled across it and taken by boat to the most upstream dike where it was firmly anchored to large rocks. Transect No. 1 was the most upstream on the distal side. The water distance was 120.4 m in May and it was separated into eight cells. Transect No. 2 was the most downstream on the distal side. The water distance was 128.32 m which was divided into nine cells. Transect No. 3 was the most upstream on the proximal side. The water distance was 123.44 m and it was separated into eight cells. Transect No. 4 was the most downstream on the proximal side. The water distance was 125.28 m, which was divided into ten cells (Table 2). The first run was carried out on 13-14 May 1991 when discharge was 762 m<sup>3</sup>/s. Mean column velocity in the distal transects (i.e., closest to the channel) was as high as 0.875 m/s. At this location nose velocity was 30% less (i.e., 0.610 m/s). Peak mean column velocity was 21% less (i.e., 0.691 m/s) in the proximal side of the dike field than in the distal side, and the nose velocity at this location was 0.418 m/s (i.e., 40% lower) (Table 2).

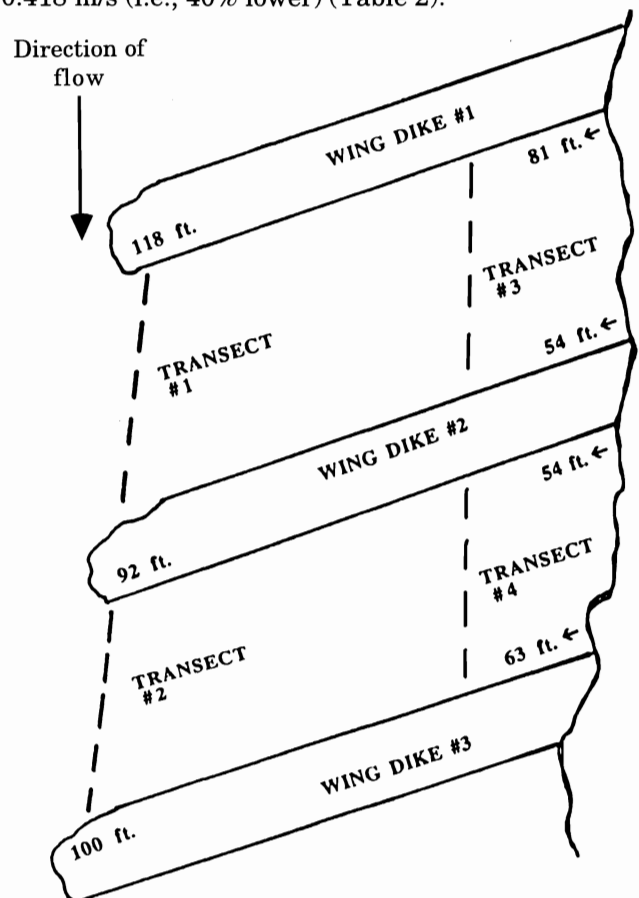


Figure 1. Dimensions associated with a study of filling-bank depth and velocity, Missouri River near Dakota City, Nebraska.

Table 2. Column velocity (mean of 0.2 and 0.8 of the depth), nose velocity, and depth on four transects in a three-wing dike (filling bank) field near Dakota City, Nebraska, from the Missouri River at river mile marker 724 on 13-14 May 1991 when discharge was 762 m<sup>3</sup>/s.

Tran- sect No.	Distance from water edge (m)	Depth (m)	Column velocity (m/s)	Nose velocity (m/s)
1	7.62	3.38	0.283	0.238
1	22.86	2.26	0.357	0.330
1	38.10	3.51	0.573	0.610
1	53.34	2.80	0.743	0.597
1	68.58	2.13	0.854	0.504
1	83.82	2.29	0.875	0.610
1	99.06	2.32	0.846	0.572
1	114.30	5.64	0.641	0.584
1	120.40	0.0	0.0	0.0
2	7.01	2.35	0.229	0.131
2	16.15	1.83	0.334	0.352
2	31.39	0.79	0.261	0.238
2	46.63	2.50	0.544	0.344
2	62.79	2.50	0.671	0.335
2	77.11	2.01	0.798	0.607
2	92.35	1.80	0.791	0.594
2	107.59	3.26	0.677	0.466
2	118.87	4.63	0.623	0.512
2	128.32	0.0	0.0	0.0
3	6.71	1.40	0.128	0.079
3	22.86	0.67	0.402	0.408
3	38.10	0.31	0.249	0.255
3	53.34	0.98	0.399	—
3	68.58	1.83	0.607	0.229
3	83.82	1.98	0.691	0.418
3	99.06	2.07	0.675	0.418
3	114.3	4.82	0.183	0.215
3	123.44	0.0	0.0	0.0
4	4.57	1.40	0.286	0.207
4	15.85	0.61	—	0.418
4	30.48	0.18	—	0.177
4	46.33	sandbar	0.0	0.0
4	55.78	sandbar	0.0	0.0
4	65.53	1.01	0.483	0.418
4	80.77	1.53	0.614	0.268
4	96.01	1.71	0.656	0.290
4	111.25	3.60	0.534	0.439
4	117.35	3.60	0.207	0.108
4	125.28	0.0	0.0	0.0

Table 3. Column velocity (mean of 0.2 and 0.8 of the depth), nose velocity, and depth on four transects in a three-wing dike (filling bank) field near Dakota City, Nebraska, from the Missouri River at river mile marker 724 on 22-23 July 1991 when discharge was 790 m<sup>3</sup>/s.

Tran- sect No.	Distance from water edge (m)	Depth (m)	Column velocity (m/s)	Nose velocity (m/s)
1	6.10	2.87	0.290	0.034
1	13.72	1.49	0.420	0.308
1	28.96	1.22	0.417	0.475
1	44.20	2.07	0.799	0.335
1	59.44	1.89	0.860	0.398
1	74.68	1.65	0.837	0.466
1	89.92	1.68	0.802	0.558
1	105.16	1.80	0.764	0.582
1	112.78	3.41	0.633	0.407
1	120.40	3.99	0.730	0.710
1	126.19	0.0	0.0	0.0
2	4.57	2.29	0.444	0.475
2	19.81	0.61	0.335	0.277
2	35.05	1.01	0.384	0.165
2	50.29	1.89	0.662	0.448
2	65.53	1.86	0.753	0.439
2	80.77	1.86	0.833	0.243
2	96.01	1.65	0.818	0.302
2	111.25	2.13	0.773	0.177
2	120.40	3.41	0.831	0.546
2	126.49	0.0	0.0	0.0
3	6.10	1.07	0.241	0.183
3	13.72	0.37	0.308	0.290
3	27.43	0.24	0.174	0.174
3	44.20	0.98	0.470	0.250
3	59.44	1.52	0.623	0.407
3	74.68	1.52	0.718	0.512
3	89.92	1.52	0.786	0.411
3	105.16	1.92	0.674	0.220
3	120.40	3.17	0.369	0.215
3	126.49	0.0	0.0	0.0
4	6.10	1.46	0.297	0.249
4	13.72	0.58	0.405	0.363
4	24.38	0.31	0.396	0.375
4	50.29	0.73	0.386	0.250
4	65.53	1.59	0.506	0.268
4	80.77	1.62	0.610	0.383
4	96.01	1.71	0.674	0.338
4	111.25	3.66	0.404	0.259
4	118.87	3.66	0.287	0.296
4	126.49	0.0	0.0	0.0

Discharge increased to 790 m<sup>3</sup>/s during the second run on 22-23 July 1991. Maximum mean column velocity in the distal transects was slightly less (i.e., 0.860 m/s) than during the first run. However, nose velocity was much lower (i.e., 0.398 m/s) at this location (i.e., -54%). Depth was reduced dramatically, most likely in response to the spring flow conditions. Periodic stage rises associated with spring run-off events appeared to have increased the sedimentation in this dike field. However, maximum mean column velocity in the proximal transects was higher this run (i.e., 0.786 m/s). Nose velocity at that location was still 48% lower than mean column velocity (Table 3).

Discharge was elevated during the 23-24 September trip to 870 m<sup>3</sup>/s. Depth increased in the dike field, most likely because higher discharge associated with reduced sediment inflow during the normal dry period of July-September allowed the sediments to be scoured away. However, maximum mean column velocity in the distal side remained the same as in July (i.e., 0.860 m/s). Nose velocity at that location was 40% less (Table 4). Maximum mean column velocity was considerably less in the proximal side (i.e., 0.578 m/s), and nose velocities were the lowest of all runs, especially in the downstream proximal transect (No. 4).

The nose velocities immediately adjacent to the rock substrate on the center wing dike decreased as discharge increased (Tables 5,6,7). The mean nose velocity in May was 0.261 m/s, 0.212 m/s in July, and 0.214 m/s in September. Current velocity was similar on the upstream and downstream sides. Mean nose velocity increased on the revetment side from May (i.e., 0.323 m/s) to July (i.e., 0.387 m/s) but then decreased slightly in September (i.e., 0.357 m/s) (Tables 5,6,7).

#### Nebraska City-Deer Island study

Volume discharge was quite different between the two sites due to large inflow from the Platte River; the Deer Island site had 405 m<sup>3</sup>/s, and the Nebraska City site had 694 m<sup>3</sup>/s. Surface velocity increased steadily in revetment habitat with distance from the water edge at Nebraska City and at Deer Island (Tekamah) (Tables 8,9; Figs. 2,3). However, surface velocity did not exceed 0.5 m/s within the first 3 m from the water edge. The depth, when velocity was 0.5 m/s, was 1.25 m at Nebraska City and about 1.4 m at Deer Island. Typically the velocity within the water column was higher than either the surface velocity or velocities at depths approaching the bottom at Nebraska City (Table 8). The surface velocity was frequently higher than either mid-column or near-bottom at Deer Island (Table 9), which may suggest a difference in the nature of the revetment substrates between the two sites or the angle of attack of the channel flows to the revetment in the study areas. However, near-bottom velocity was commonly

Table 4. Column velocity (mean of 0.2 and 0.8 of the depth), nose velocity, and depth on four transects in a three-wing dike (filling bank) field near Dakota City, Nebraska, from the Missouri River at river mile marker 724 on 23-24 September 1991 when discharge was 870 m<sup>3</sup>/s.

Tran- sect No.	Distance from water edge (m)	Depth (m)	Column velocity (m/s)	Nose velocity (m/s)
1	7.62	3.81	0.390	0.049
1	22.86	1.52	0.459	0.390
1	38.10	1.65	0.521	0.375
1	53.34	2.68	0.657	0.555
1	68.58	2.87	0.771	0.500
1	83.82	3.11	0.779	0.375
1	99.06	3.35	0.814	0.360
1	114.30	6.13	0.656	0.196
1	126.49	0.0	0.0	0.0
2	6.10	2.10	0.294	0.290
2	21.34	0.61	0.466	0.390
2	36.58	0.27	0.147	0.117
2	51.82	1.68	0.566	0.177
2	67.06	1.83	0.717	0.448
2	82.3	2.04	0.804	0.488
2	97.54	2.19	0.860	0.512
2	118.87	5.46	0.709	0.255
2	128.02	0.0	0.0	0.0
3	6.10	1.46	0.137	0.134
3	22.86	0.40	0.457	0.314
3	47.24	0.31	0.320	0.255
3	60.96	0.67	0.309	0.174
3	76.20	1.19	0.578	0.326
3	91.44	2.10	0.393	0.215
3	106.68	2.35	0.363	0.127
3	121.92	3.51	0.286	0.140
3	126.49	0.0	0.0	0.0
4	7.01	0.67	0.076	0.082
4	42.67	0.31	0.182	0.085
4	57.91	1.21	0.269	0.094
4	73.15	1.52	0.311	0.158
4	88.39	1.65	0.416	0.229
4	103.63	2.87	0.266	0.174
4	118.87	3.87	0.186	0.108
4	126.49	0.0	0.0	0.0

Table 5. Nose velocities at selected locations on a wing dike (filling bank) and on a revetment (cutting bank) on the Missouri River near Dakota City, Nebraska, on 13 May 1991 at river mile marker 724.

Sample location	Depth (m)	Nose velocity (m/s)
Wing dike, downstream, distal	1.55	0.302
Wing dike, downstream, distal	1.13	0.262
Wing dike, downstream, proximal	0.91	0.168
Wing dike, upstream, distal	1.28	0.296
Wing dike, upstream, distal	1.07	0.314
Wing dike, upstream, proximal	1.40	0.233
Wing dike, upstream, proximal	0.95	0.249
Revetment	0.82	0.466
Revetment	1.19	0.308
Revetment	1.25	0.375
Revetment	1.51	0.243
Revetment	2.01	0.224

Table 6. Nose velocities at selected locations on a wing dike (filling bank) and on a revetment (cutting bank) on the Missouri River near Dakota City, Nebraska, on 22 July 1991 at river mile marker 724.

Sample location	Depth (m)	Nose velocity (m/s)
Wing dike, downstream, distal	1.01	0.261
Wing dike, downstream, distal	1.49	0.352
Wing dike, downstream, proximal	0.82	0.174
Wing dike, upstream, distal	1.52	0.344
Wing dike, upstream, distal	1.04	0.152
Wing dike, upstream, proximal	1.40	0.119
Wing dike, upstream, proximal	1.16	0.085
Revetment	0.85	0.439
Revetment	1.16	0.320
Revetment	1.28	0.511
Revetment	1.53	0.207
Revetment	1.74	0.457

lower than mid-column or surface velocity at the deepest locations at both sites.

Figure 4 provides a perspective on column velocity within the broader context of the total main channel of the channelized reach. These USGS data showed that maximum column velocity occurred about 40 m from the cutting bank water edge and subsequently decreased to each bank in all three months sampled, which represented three distinctly different discharge volumes. The

Table 7. Nose velocities at selected locations on a wing dike (filling bank) and on a revetment (cutting bank) on the Missouri River near Dakota City, Nebraska, on 23 September 1991 at river mile marker 724.

Sample location	Depth (m)	Nose velocity (m/s)
Wing dike, downstream, distal	2.04	0.268
Wing dike, downstream, distal	1.28	0.207
Wing dike, downstream, proximal	1.59	0.224
Wing dike, upstream, distal	2.13	0.162
Wing dike, upstream, distal	1.49	0.210
Wing dike, upstream, proximal	1.37	0.290
Wing dike, upstream, proximal	2.01	0.134
Revetment	0.91	0.262
Revetment	1.22	0.418
Revetment	1.22	0.229
Revetment	1.95	0.594
Revetment	1.95	0.283

decrease in velocity was precipitous as the cutting bank was approached.

The USGS velocity data from the channel margins were similar to the velocity data obtained in this study at similar distances (e.g., 0.680 m/s at about 20 m from the filling bank (Table 10) vs. 0.691 m/s maximum mean column velocity in Transect No. 3 (Table 2); and 0.604 m/s at 4.57 m from the cutting bank in February vs. 0.716 m/s mean column velocity at 4.56 m in March (Table 8).

## DISCUSSION

Layher and Brunson (1992) developed suitability curves for total fish standing stocks in six moderate sized streams in eastern Kansas. Maximum mean standing crop was given a 1.0 suitability index when mean velocity was 0.9 m/s. Humpback chub adults in the Colorado, Green and Yampa rivers, on average, used a flow velocity of 0.18 m/s in a range of observations between 0 and 1.19 m/s (Valdez et al., 1990). Gore and Judy (1981) estimated velocity preference for 18 species of invertebrates. These organisms utilized a wide range of velocities from 0.064 m/s to 1.31 m/s. Some larval fish prefer low velocity; 2–4-week-old rainbow and brown trout frequented areas with velocity ranging from 0 to 0.24 m/s (Nehring and Anderson, 1993). Colorado squawfish spawning habitat developed among sandbars in the lower Yampa River when discharge ranged between 11.3 and 141.6 m<sup>3</sup>/s, when velocity ranged from 1.07 to 2.65 m/s.



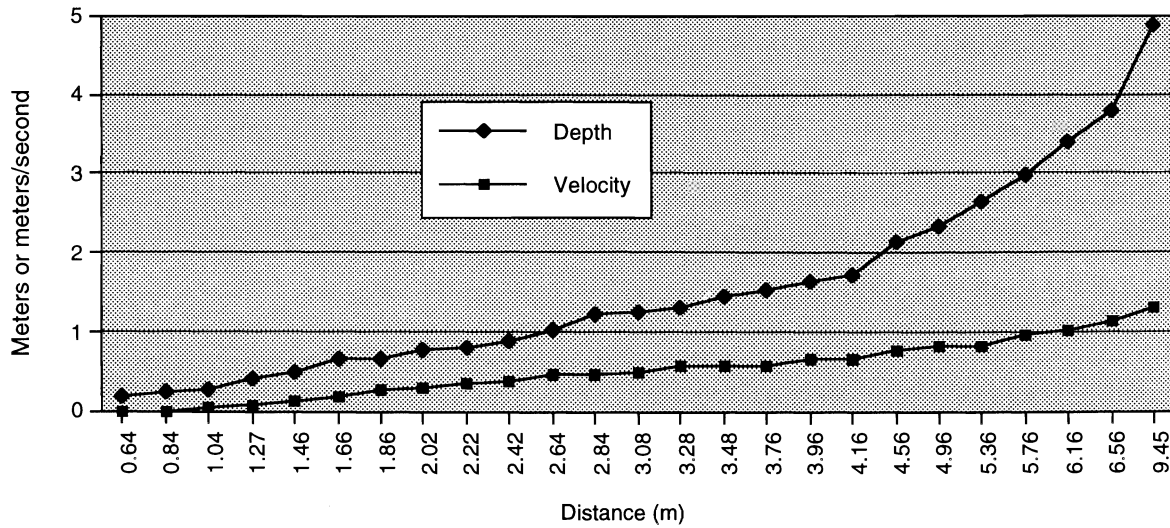


Figure 2. Depth and surface velocity as it varies with distance from the water's edge of the Missouri River at Nebraska City, Nebraska.

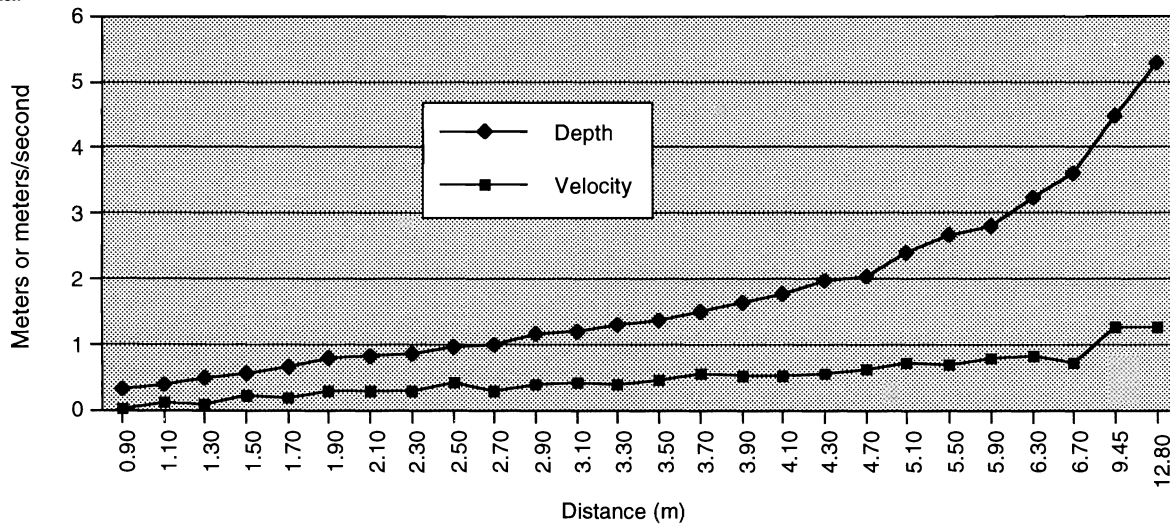


Figure 3. Depth and surface velocity as it varies with distance from the water's edge of the Missouri River at Deer Island near Tekamah, Nebraska.

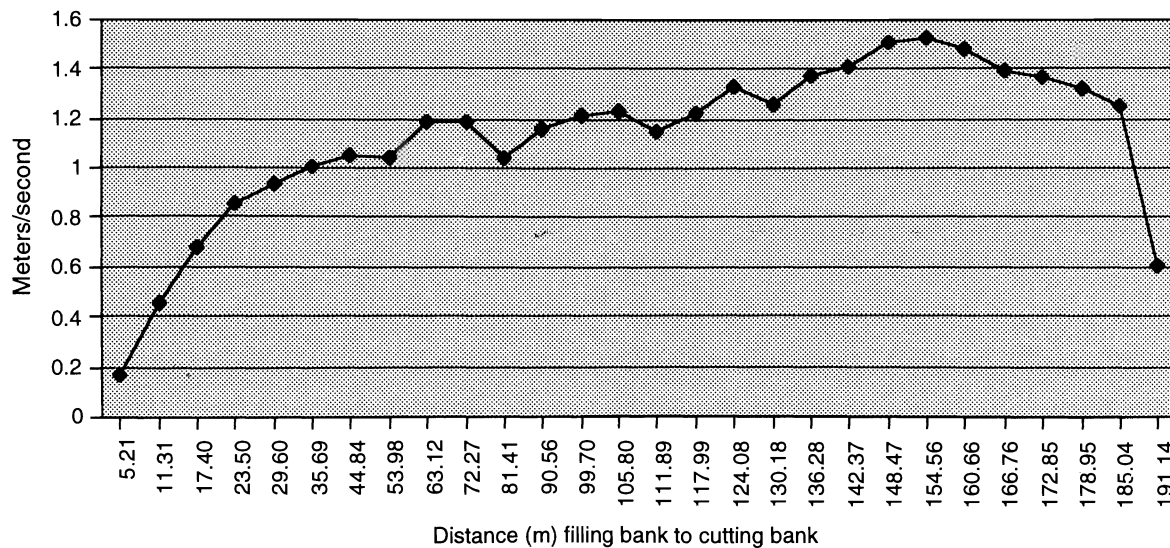


Figure 4. Column velocity profile of the channel of the Missouri River at Nebraska City, Nebraska on 26 February, 1991. The cutting bank is on the right.



Table 8. Current velocities at the surface and at selected depths at small incremental distances from the water edge of a revetment (cutting bank). Velocities obtained on 3 March 1992 near Nebraska City, Nebraska, from the Missouri River at river mile marker 564.6. Surface velocity taken at a standardized meter depth of 100 mm. Data not available = n/a.

Distance from water edge (m)	Depth (m)	Surface velocity (m/s)	Column velocity (m/s)			
			at 0.6 m	at 1.2 m	at 1.8 m	at 2.4 m
0.64	0.18	0.0	n/a	n/a	n/a	n/a
0.84	0.24	0.0	n/a	n/a	n/a	n/a
1.04	0.27	0.049	n/a	n/a	n/a	n/a
1.27	0.41	0.085	n/a	n/a	n/a	n/a
1.46	0.49	0.125	n/a	n/a	n/a	n/a
1.66	0.67	0.186	0.229	n/a	n/a	n/a
1.86	0.67	0.277	0.308	n/a	n/a	n/a
2.02	0.79	0.302	0.428	n/a	n/a	n/a
2.22	0.82	0.352	0.500	n/a	n/a	n/a
2.42	0.90	0.383	0.546	n/a	n/a	n/a
2.64	1.02	0.466	0.558	n/a	n/a	n/a
2.84	1.22	0.475	0.634	n/a	n/a	n/a
3.08	1.25	0.500	0.680	0.296	n/a	n/a
3.28	1.31	0.570	0.680	0.500	n/a	n/a
3.48	1.45	0.582	0.725	0.634	n/a	n/a
3.76	1.52	0.594	0.756	0.680	n/a	n/a
3.96	1.65	0.664	0.771	0.710	n/a	n/a
4.16	1.74	0.680	0.808	0.741	n/a	n/a
4.56	2.16	0.771	0.756	0.826	0.512	n/a
4.96	2.35	0.847	0.969	0.905	0.664	n/a
5.36	2.65	0.847	1.018	0.927	0.789	n/a
5.76	2.99	0.969	1.085	1.018	0.847	n/a
6.16	3.40	1.018	1.064	0.927	0.826	n/a
6.56	3.78	1.155	1.106	1.085	0.969	n/a
9.45	4.88	1.131	1.323	1.356	1.445	1.356

Table 8. Continued.

Distance from water edge (m)	Depth (m)	Surface velocity (m/s)	Column velocity (m/s)			Nose velocity at 4.88 m
			at 3.05 m	at 3.66 m	at 4.27 m	
9.45	4.88	1.131	1.323	1.064	0.826	0.680

"Current is the most significant characteristic of running water, and it is in their adaptations to constantly flowing water that many stream animals differ from their still-water relatives" (Hynes, 1970). Aquatic organisms in large rivers have adapted to high current and in fact many species have an innate demand for high water velocities, depending on them to continually supply adequate nutrients and oxygen (Gordon et al., 1993). The Missouri River was always a high current velocity stream as demonstrated by the species adaptations (e.g., sturgeon chub, blue sucker). Fusiform bodies and special scalation characterized the most adaptive. River training for flood control and navigation can

have some important consequences on velocity and thus channel morphology. Although thalweg velocity was typically high even in natural channels, near-bank velocities were often increased when channels were straightened and narrowed (Kellerhals and Church, 1989). It is the near-bank areas along river channels that many river species live out their lives (Stalnaker et al., 1989). These authors pointed out that the mean column velocity may considerably exceed the near-bottom velocity in large rivers. Moreover, fish change position in the water column in response to changing velocity by often moving toward the bottom. Therefore, nose velocity must be used in habitat studies; this point

Table 9. Current velocities at the surface and at selected depths at small incremental distances from the water edge of a revetment (cutting bank). Data obtained on 4 March 1992 near Tekamah, Nebraska from the Missouri River at river mile marker 672.3. Surface velocity taken at a standardized depth of 100 mm. Data not available = n/a.

Distance from water edge (m)	Depth (m)	Surface velocity (m/s)	Column velocity			
			at 0.6 m	at 1.2 m	at 1.8 m	at 2.4 m
0.90	0.32	0.027 back.	n/a	n/a	n/a	n/a
1.10	0.40	0.127	n/a	n/a	n/a	n/a
1.30	0.51	0.108	n/a	n/a	n/a	n/a
1.50	0.58	0.243	n/a	n/a	n/a	n/a
1.70	0.67	0.207	n/a	n/a	n/a	n/a
1.90	0.79	0.296	0.200	n/a	n/a	n/a
2.10	0.82	0.302	0.261	n/a	n/a	n/a
2.30	0.88	0.283	0.290	n/a	n/a	n/a
2.50	0.98	0.428	0.338	n/a	n/a	n/a
2.70	1.01	0.314	0.383	n/a	n/a	n/a
2.90	1.16	0.387	0.418	n/a	n/a	n/a
3.10	1.21	0.439	0.428	n/a	n/a	n/a
3.30	1.30	0.412	0.418	0.238	n/a	n/a
3.50	1.37	0.475	0.457	0.290	n/a	n/a
3.70	1.51	0.570	0.512	0.335	n/a	n/a
3.90	1.65	0.546	0.512	0.408	n/a	n/a
4.10	1.77	0.533	0.466	0.383	n/a	n/a
4.30	1.97	0.582	0.533	0.500	0.122	n/a
4.70	2.04	0.619	0.649	0.594	0.314	n/a
5.10	2.41	0.741	0.664	0.619	0.506	n/a
5.50	2.68	0.695	0.826	0.695	0.515	n/a
5.90	2.80	0.808	0.808	0.808	0.582	n/a
6.30	3.23	0.826	0.789	0.808	0.710	n/a
6.70	3.60	0.741	0.826	0.826	0.808	n/a
9.45	4.48	1.280	1.356	1.292	1.323	1.262
12.80	5.30	n/a	n/a	n/a	n/a	1.204

Table 9. Continued.

Distance from water edge (m)	Depth (m)	Column velocity			Nose velocity at 4.48 m	Column velocity at 4.48 m	Nose velocity at 5.3 m
		at 3.05 m	at 3.66 m	at 4.27 m			
9.45	4.48	1.180	1.106	0.741	0.588	n/a	n/a
12.08	5.30	1.106	1.204	1.042	n/a	0.808	0.512

has often been overlooked and the habitat suitability will be dramatically underestimated when nose velocity is not used (Stalnaker et al., 1989). Stalnaker et al. (1989) also pointed out that for large-river fish assemblages, the only appreciable overhead cover existed in a narrow strip along both edges of the stream. What happened in the middle of the river was of little importance to the habitat needs, except that water level in the channel controlled the depths and velocities in the edges to some degree.

Hynes (1970) noted that the actual currents experienced by animals on stream beds were very much less than those which could be measured effectively by current meters. Therefore it was very important to carefully evaluate velocity relationships in both natural or altered streams because in turbulent flow, the force exerted by water increased as the square of the current, and small animals might quickly find velocity too much to resist if they did not find mitigating habitats, near the highest current areas.

Table 10. Current velocities on a cross-section transect of the Missouri River at river mile marker 564.6 near Nebraska City on 7 December 1990 when discharge was measured at 484 m<sup>3</sup>/s; on 26 February 1991 when discharge was measured at 640 m<sup>3</sup>/s; and on 24 April 1991 when discharge was measured at 1,045 m<sup>3</sup>/s. Data were obtained by the U.S.G.S. for the U.S.A.C.O.E. for Master Manual studies and reported in unpublished interim documents. Distance is from the filling bank toward the cutting bank.

Distance from water edge (m) Dec/Feb/Apr	Mean column velocity (m/s)		
	December 1990	February 1991	April 1991
3.23/5.21/5.18	0.119	0.168	0.082
9.33/11.31/11.28	0.357	0.454	0.226
15.42/17.40/17.37	0.543	0.680	0.567
21.52/23.50/23.47	0.643	0.860	0.841
27.62/29.60/29.57	0.671	0.936	1.116
33.71/35.69/35.66	0.750	1.009	1.250
42.85/44.84/41.76	0.789	1.055	1.317
52.00/53.98/50.90	0.826	1.046	1.372
61.14/63.12/60.05	0.972	1.186	1.305
70.29/72.27/69.19	1.027	1.189	1.427
79.43/81.41/78.33	0.914	1.042	1.360
88.57/90.56/87.48	1.027	1.161	1.177
97.72/99.70/96.62	1.061	1.216	1.300
103.82/105.80/105.77	1.067	1.231	1.378
109.91/111.89/111.86	1.009	1.149	1.408
116.01/117.99/117.96	1.079	1.219	1.300
122.10/124.08/124.05	1.167	1.329	1.363
128.19/130.18/130.15	1.122	1.259	1.494
134.30/136.28/136.25	1.210	1.378	1.396
140.39/142.37/142.34	1.219	1.408	1.555
146.49/148.47/148.44	1.314	1.512	1.609
152.58/154.56/154.53	1.338	1.524	1.722
158.68/160.66/160.63	1.323	1.484	1.713
164.77/166.76/166.73	1.247	1.393	1.646
170.87/172.85/172.82	1.231	1.369	1.536
176.97/178.95/178.92	1.183	1.320	1.500
183.06/185.04/185.01	1.131	1.253	1.451
189.16/191.14/191.11	0.424	0.604	1.366
193.73/195.71/197.21	—	—	0.820

Very rough bottoms, such as those occurring along the margins of the channelized Missouri River, may totally nullify the impact of increased mean velocity resulting from channelization. In fact the greater factor in such an altered river is the role that changing volume discharge (and thus velocity) has had on the dynamics of channel morphology, since channel morphology was a function of discharge and sediment quantity and quality, and channel morphology represented critical physical habitat for all native species of flora and fauna (Gore and Shields, 1995).

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